Silicon Tracking:

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Brief History.

Understanding of SVX/ISL Material & its effects.
- --Hadronic & electromagnetic interactions.
- --Multiple scattering.

Description of pattern recognition algorithms.

Benchmarks
- --Single muons.
- --Single pions.
- --Top events

Plans for further development.
- --Short term (getting this to customers)
- --Mid term (production executable)
- --Long term (mock data challenge, data taking)

Plans for documentation.

Manpower needs.

Other needs

Brief History.

* January, all algorithms mostly implemented.
  (Exceptions: material integrator, optimizer).
  Monte Carlo needed for debugging.

* March, a combined tracking module is available
  (SvxCotTracking, Chris Green).

* April, first Geant Monte Carlo containing silicon.

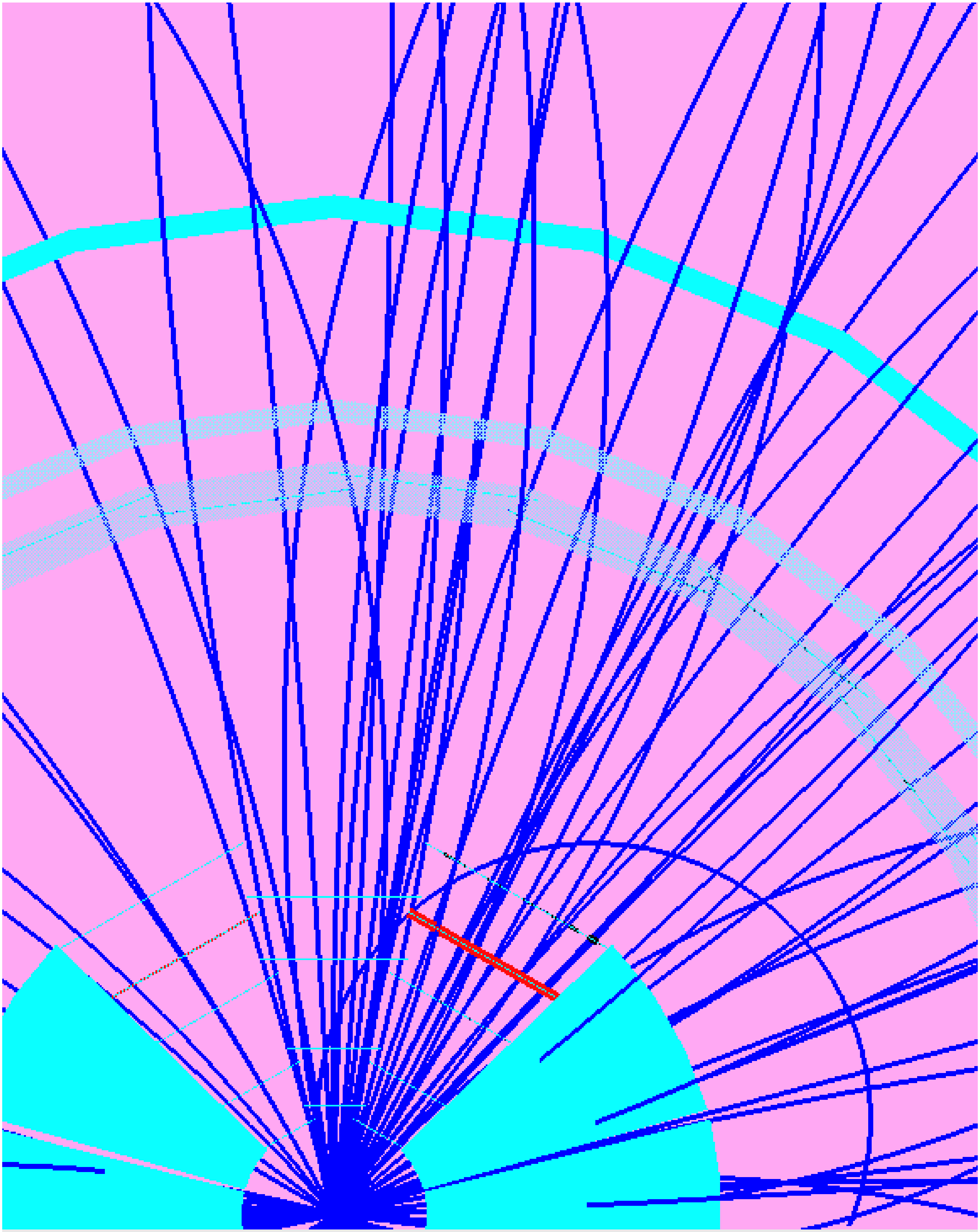
* May, understanding of material improves.
  single muons well understood.
  small events become available.
  benchmarking tasks developed.

* June, studies of small, locally dense events, debugging, and use of an optimizer for resolving hit contention.

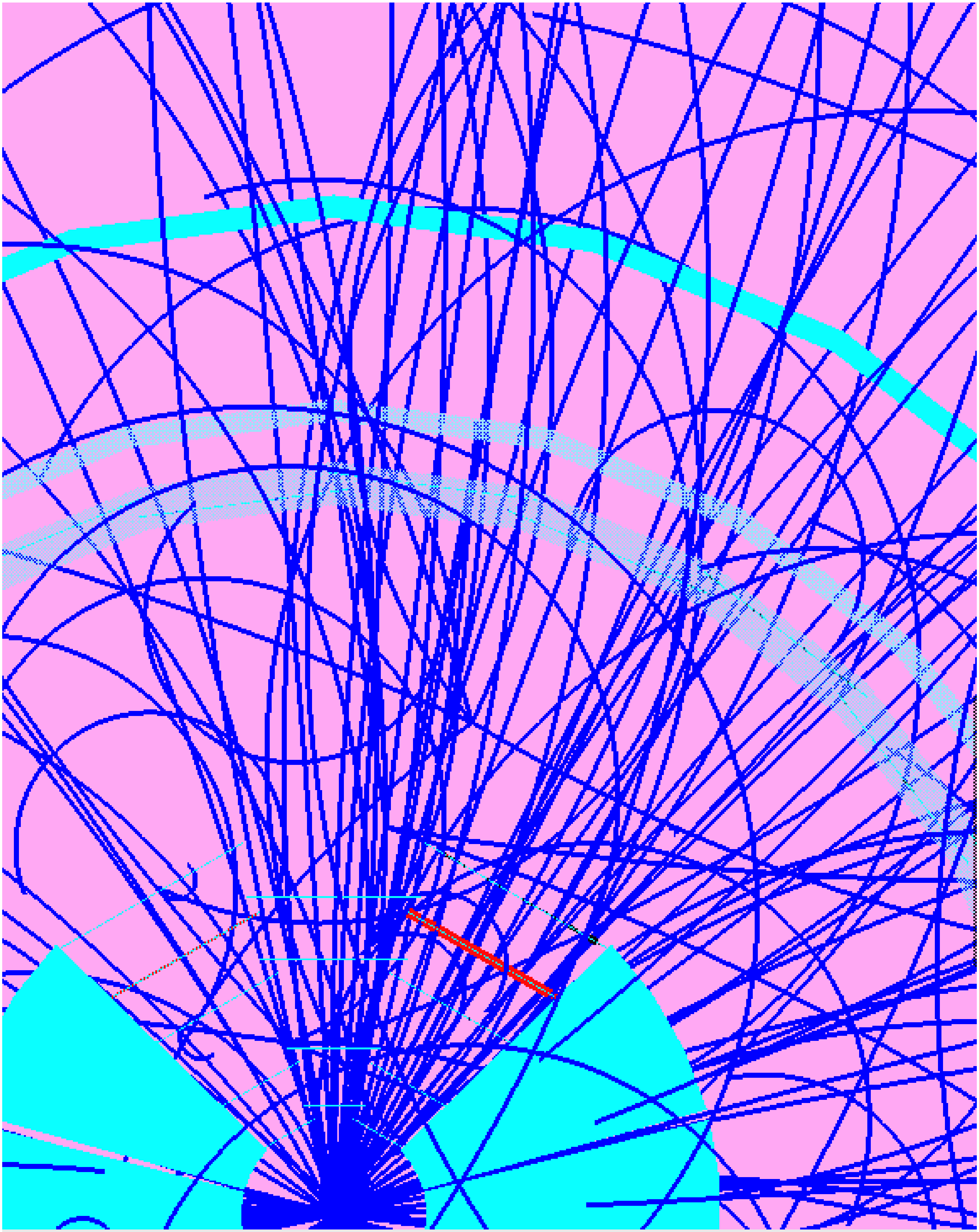
* July, first look at top events.

Present results test data persistence, clustering, track fitting, track finding material integration, z vertex fitting*, and the sensibility of output banks.

* throughout this talk, we cheat on z vertex finding by peeking at the Monte Carlo truth information.

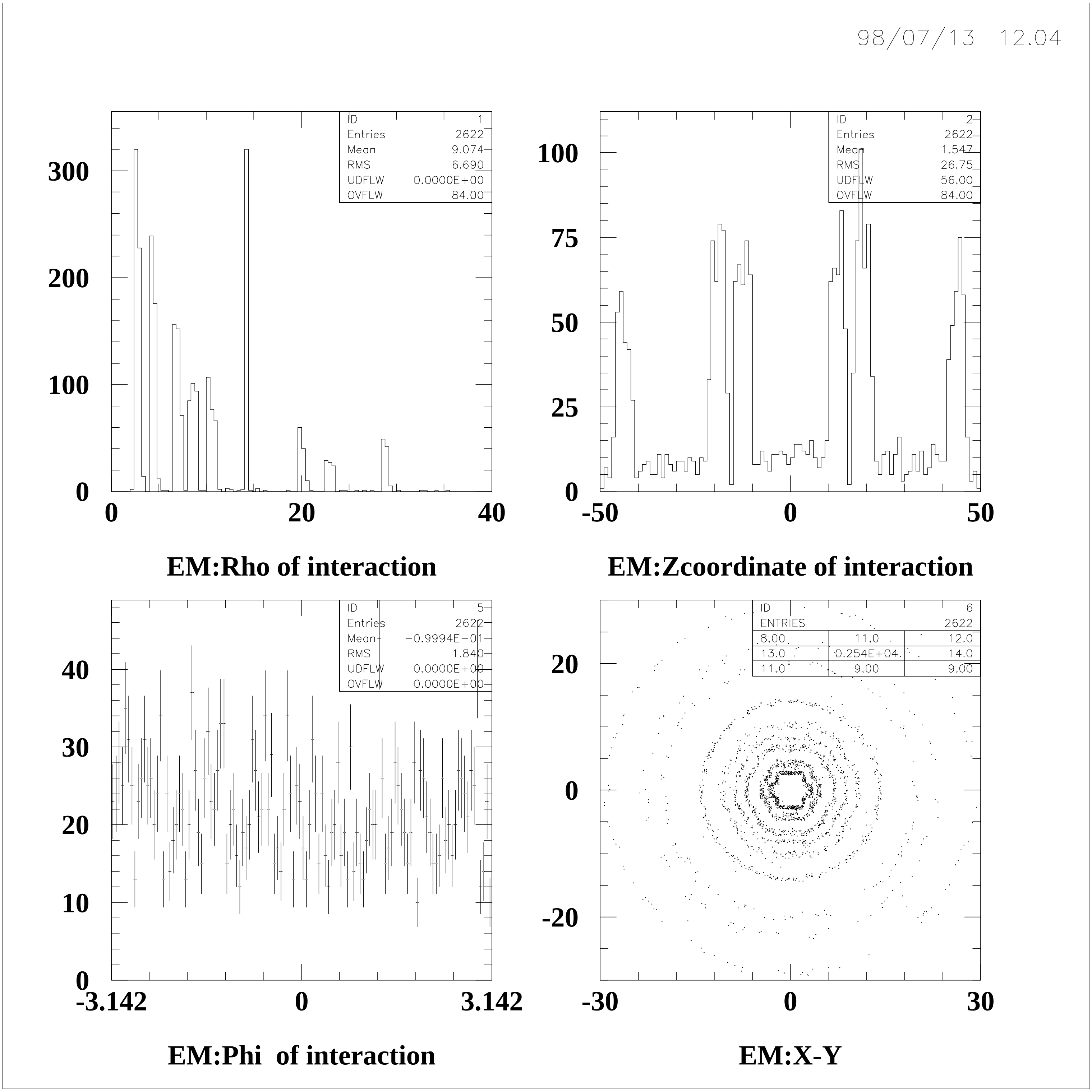


Top Event Without Showers.

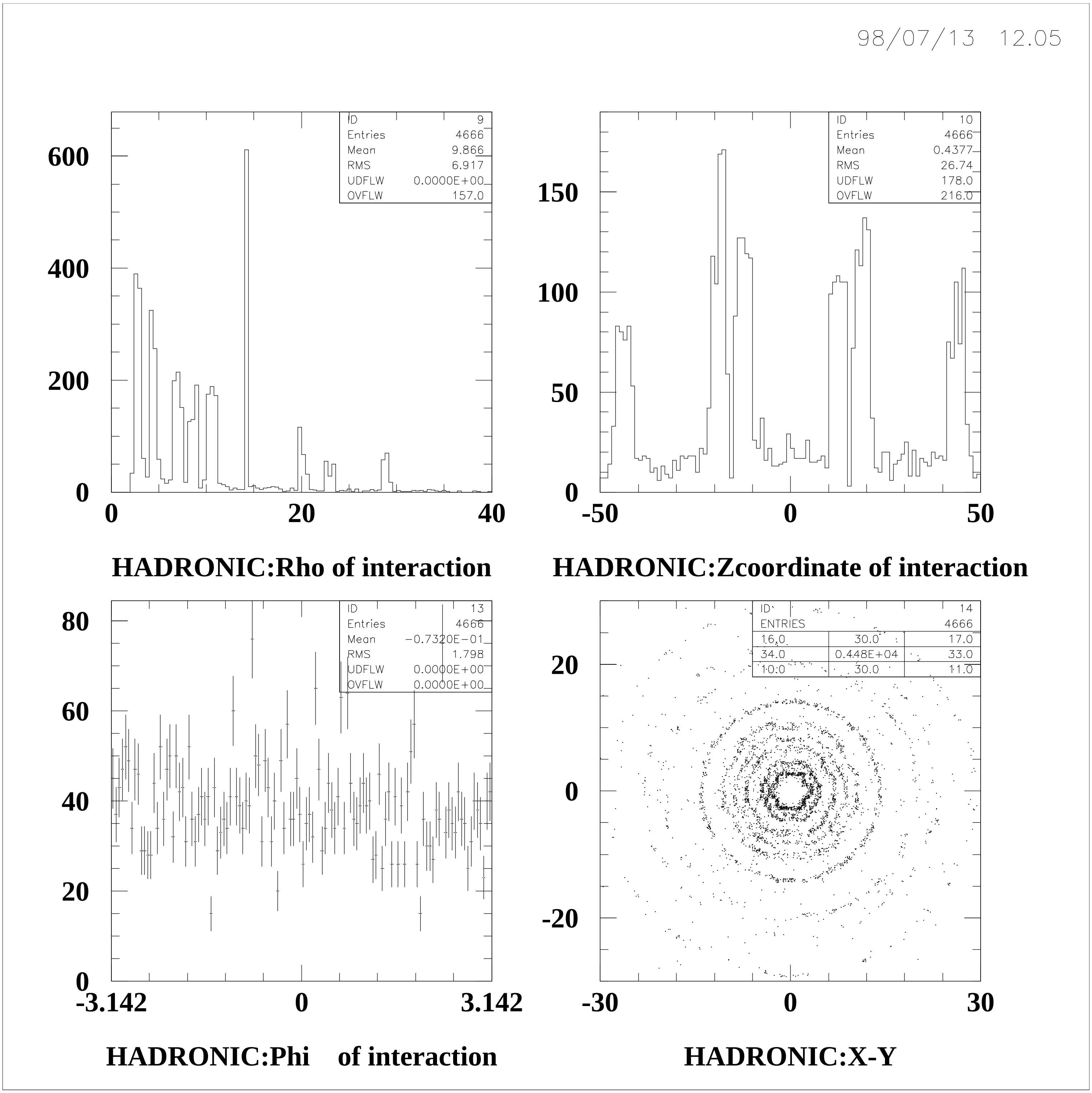


Top Event With Showers.

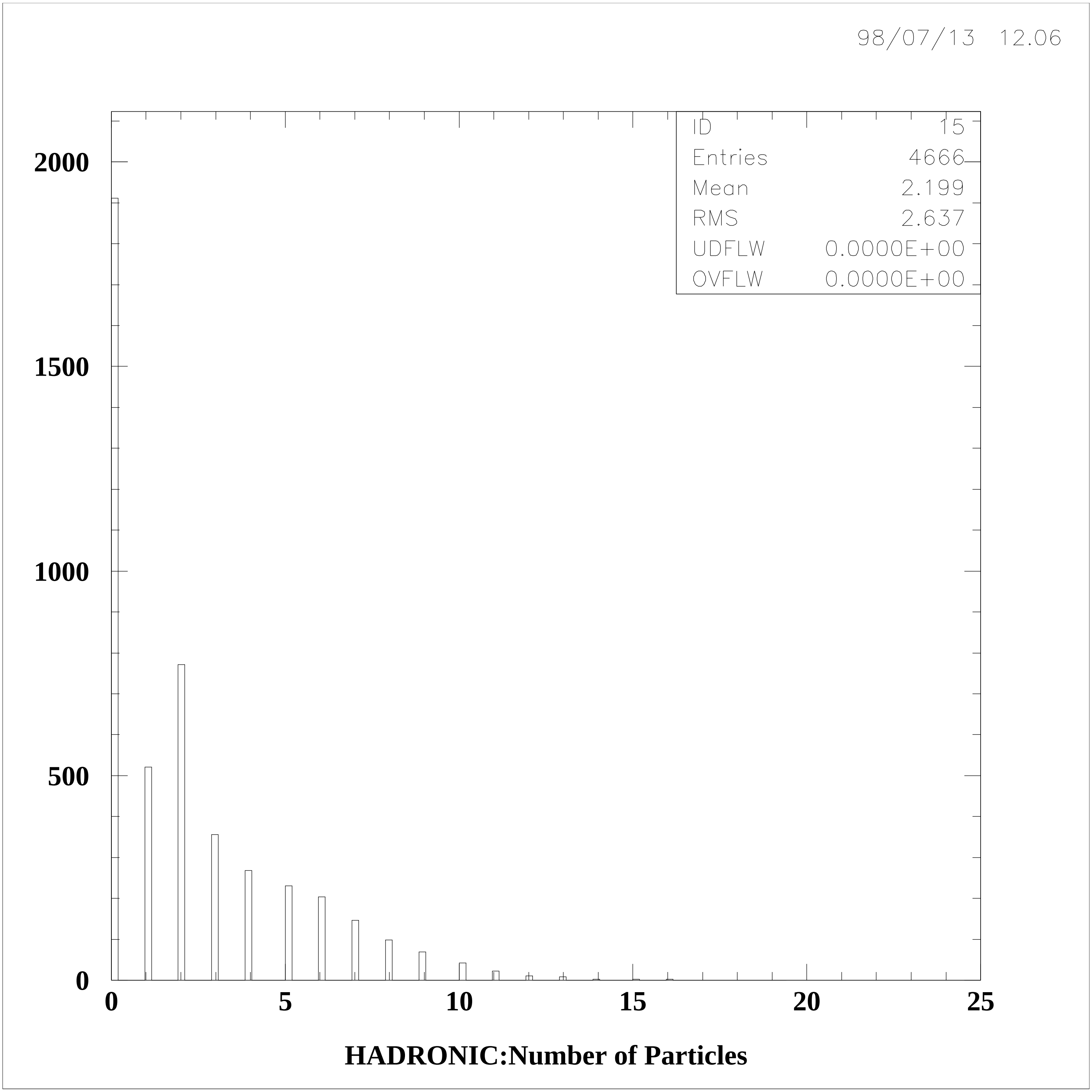
Photon conversions in the silicon, $E_\gamma > 50$ MeV



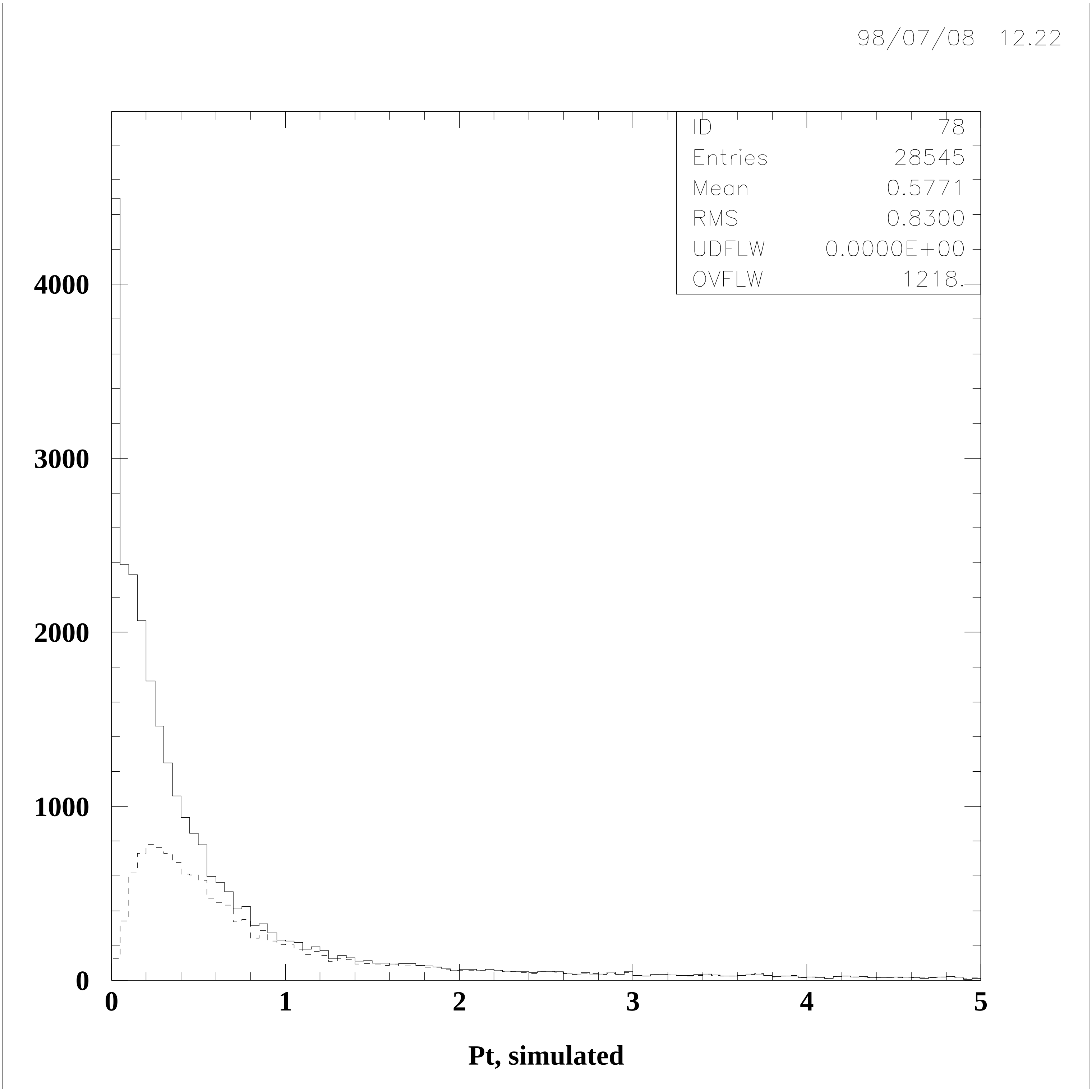
Hadron showers in the silicon, $E_{had} > 50$ MeV



Number of daughters in hadronic showers with p>50MeV.



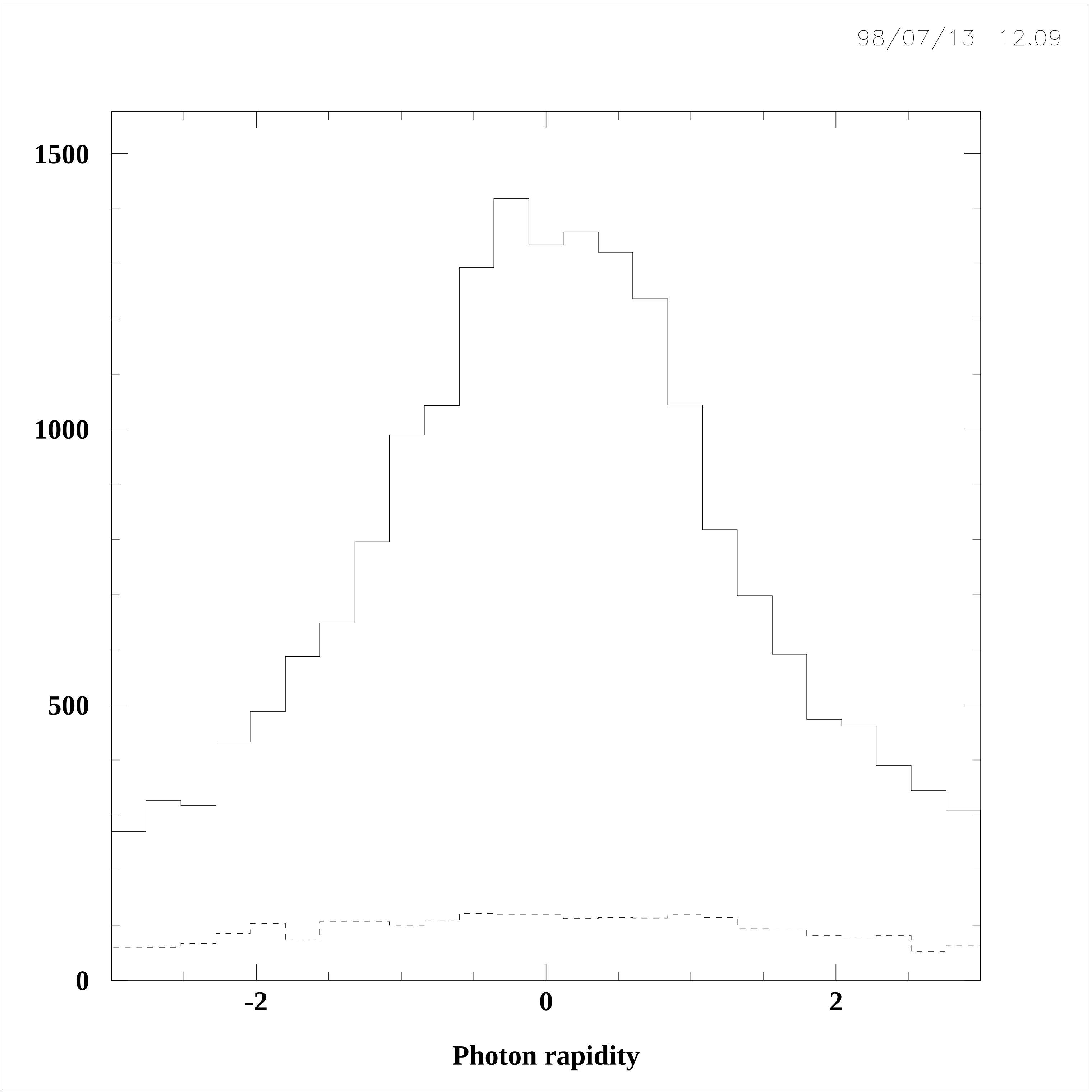
Charged, stable tracks in detector simulation shown with charged, stable tracks at generator level.



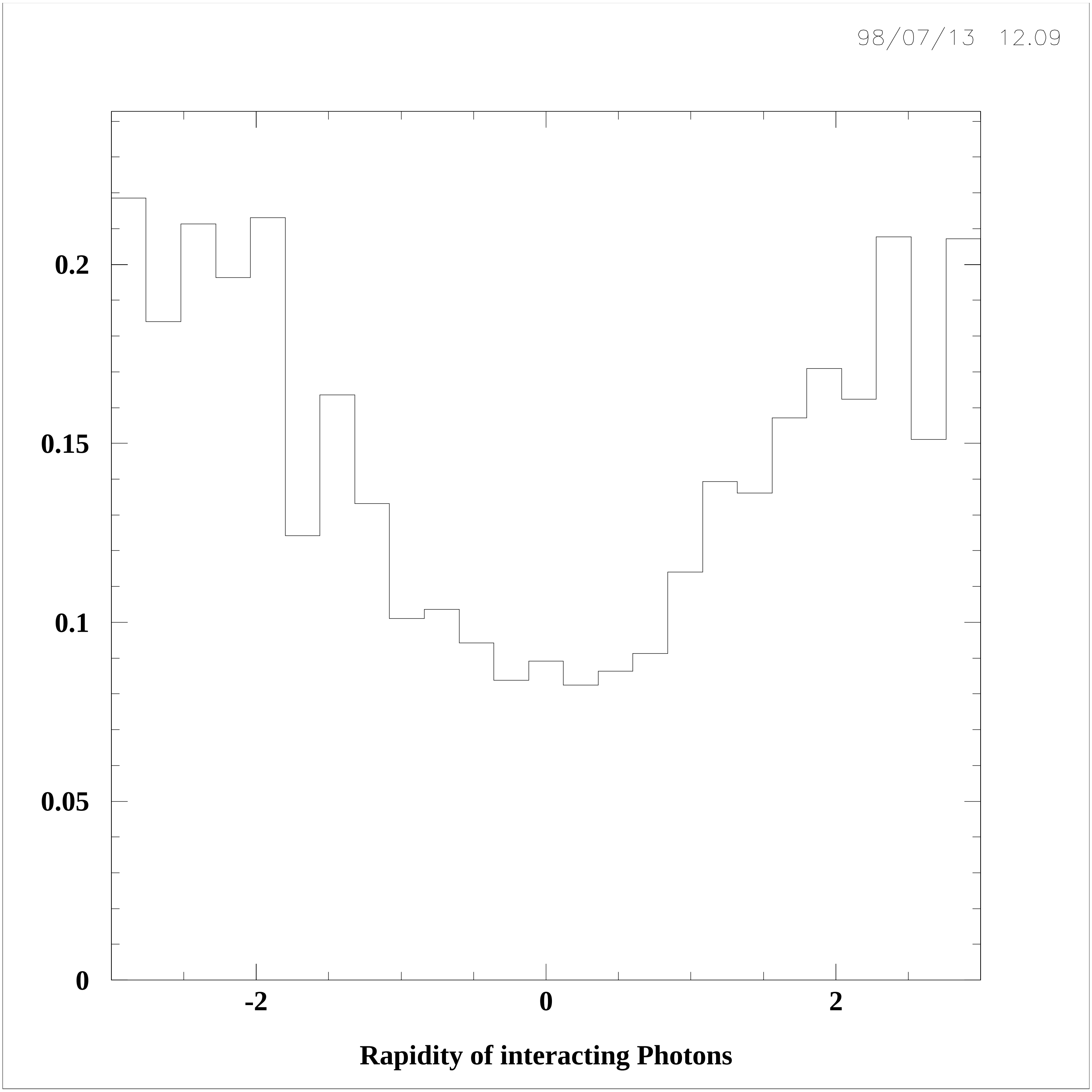
solid line: simulated (includes generated)
dashed line: generated.

Rapidity of all photons, and rapidity of interacting photons

$E\gamma > 50MeV$



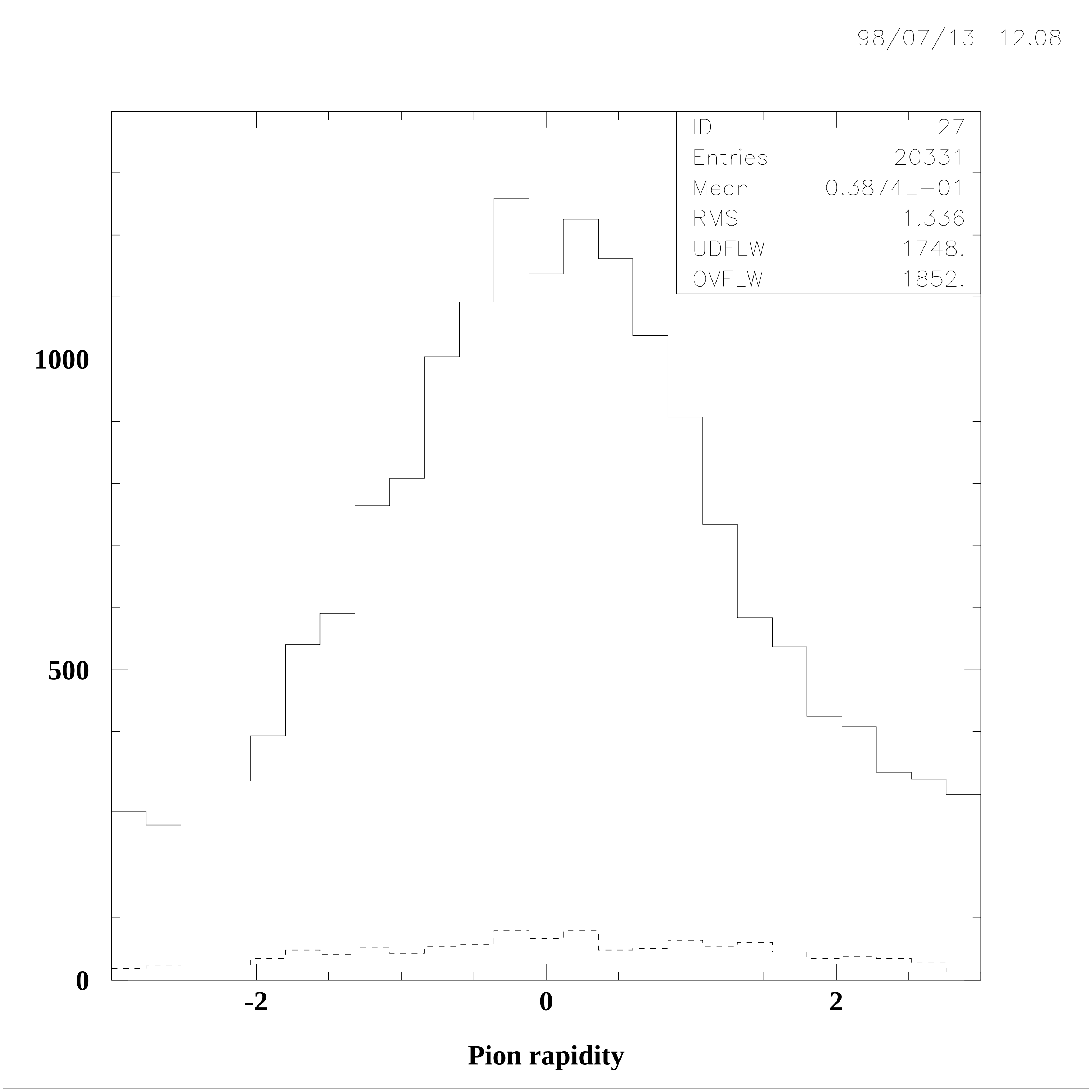
Interaction probability for photons $E_\gamma > 50$ MeV vs rapidity



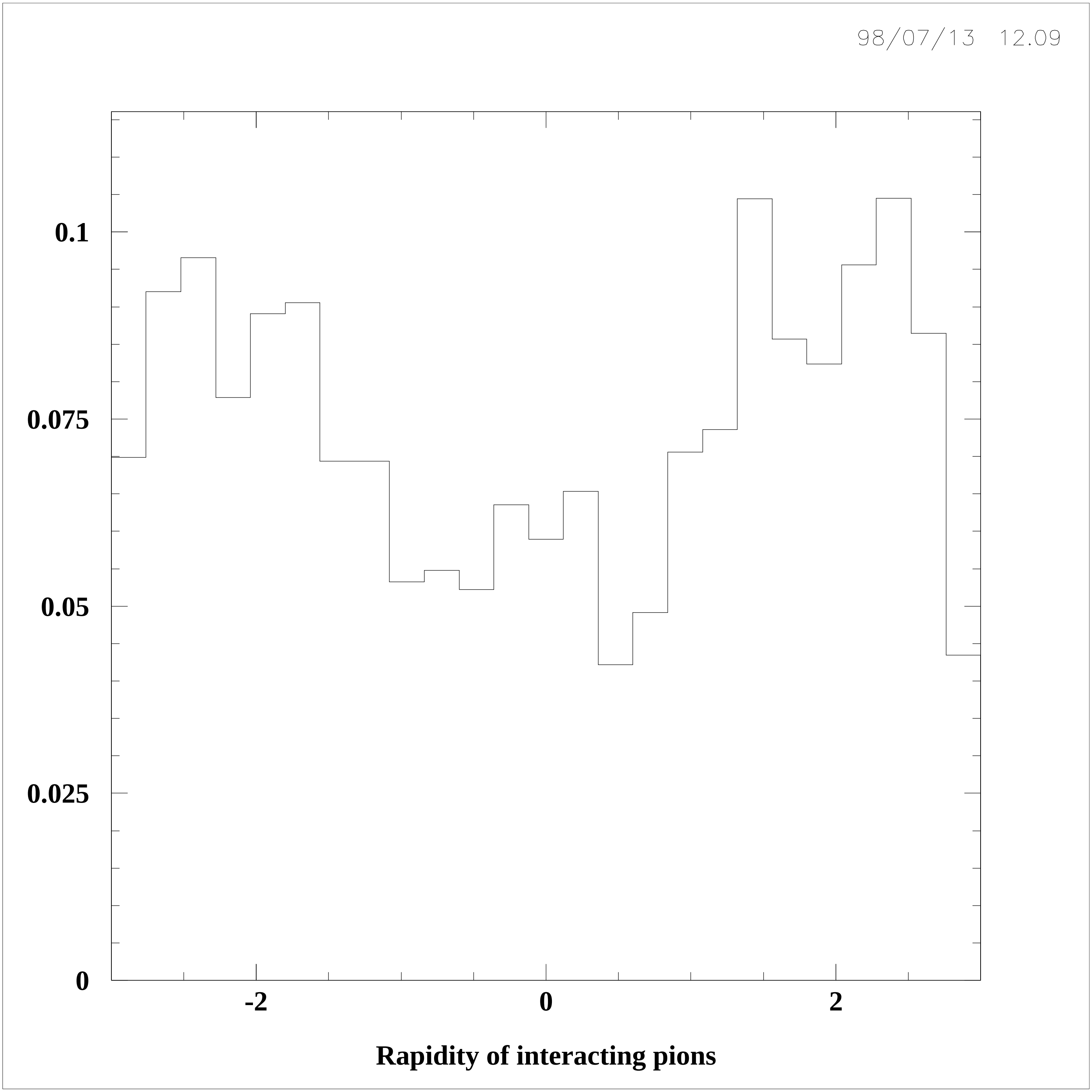
(Agrees well with expectations)

Rapidity of all pions, and rapidity of interacting pions

$E_\pi > 50MeV$



Interaction probability for pions $E_{\pi} > 50$ MeV vs rapidity



~5.5 % of an interaction length at normal incidence.

Material: Multiple scattering.

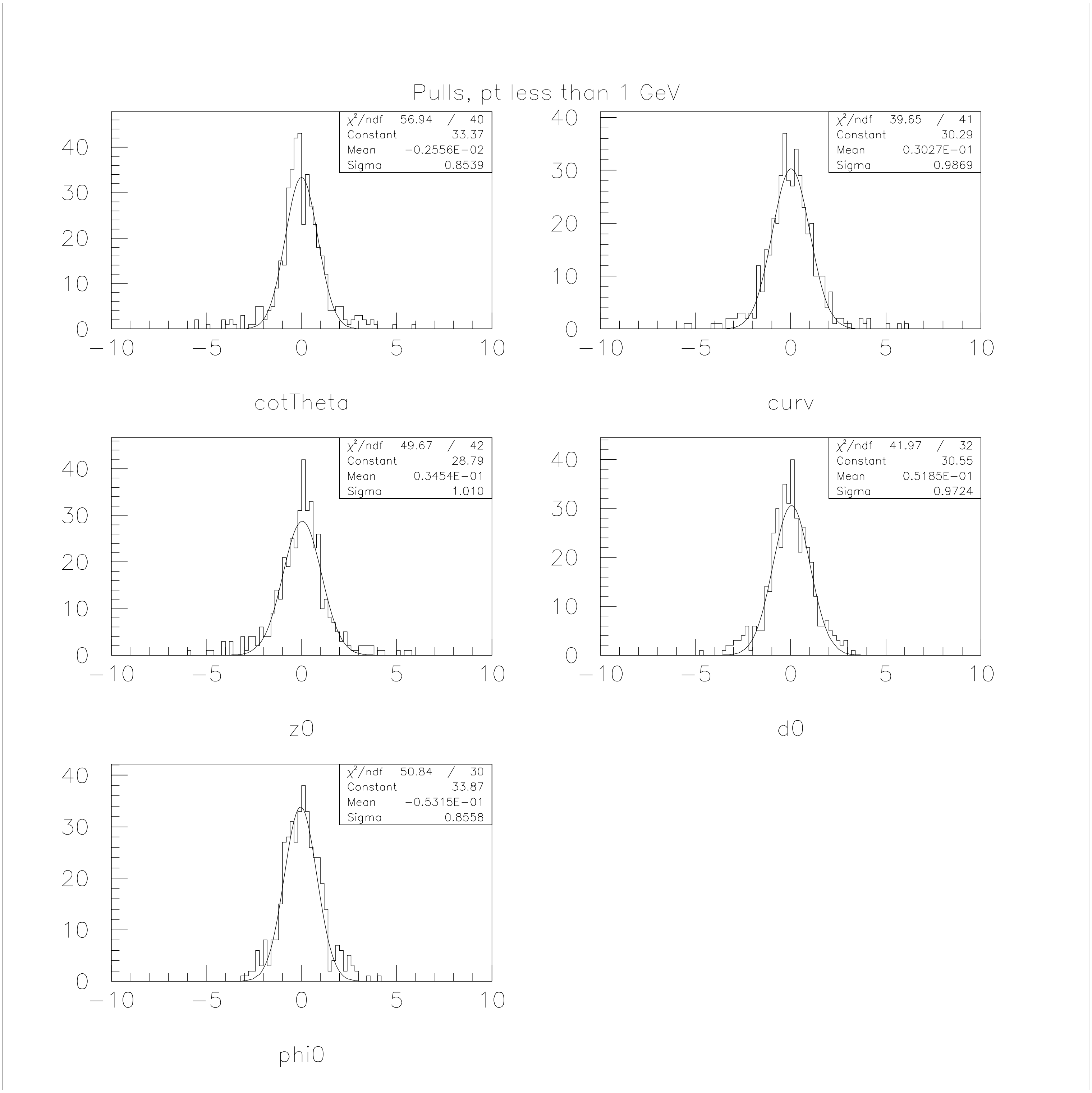
* Multiple scattering is crucial to an accurate fit, also critical to pattern recognition, which relies on χ^2 as a final test of track quality.

* The material is estimated using a "material integrator" that adds up material along a trajectory between two different measurement points.

* It is incorporated using the Progressive Fitter.

* The pull distributions will have width unity if hit resolutions and Multiple Scattering are accurately known and incorporated.

Today, we have the following pull distributions (single muon events, tracks under 1 GeV):



Widths: 0.85, 0.99, 1.01, 0.97, 0.86

Widths, 1-20 GeV muons:

1.02, 1.09, 1.14, 0.92, 0.95

Pull distributions measured before incorporation of multiple scattering:

5 GeV Sigmas: 2.3, 2.0, 1.7, 2.0, 1.9.

Projections:

2.5 GeV Sigmas of 5
1 GeV Sigmas of 10

Dramatic effect on the efficiency of low-energy muons if multiple scattering is left out: efficiency goes from 87% to 23% for muons less than 0.4-1 GeV.

One number that gives a feel for the size of the effect: a 5 GeV track will scatter by 100 microns by the time it reaches the ISL.

==> Consequences:

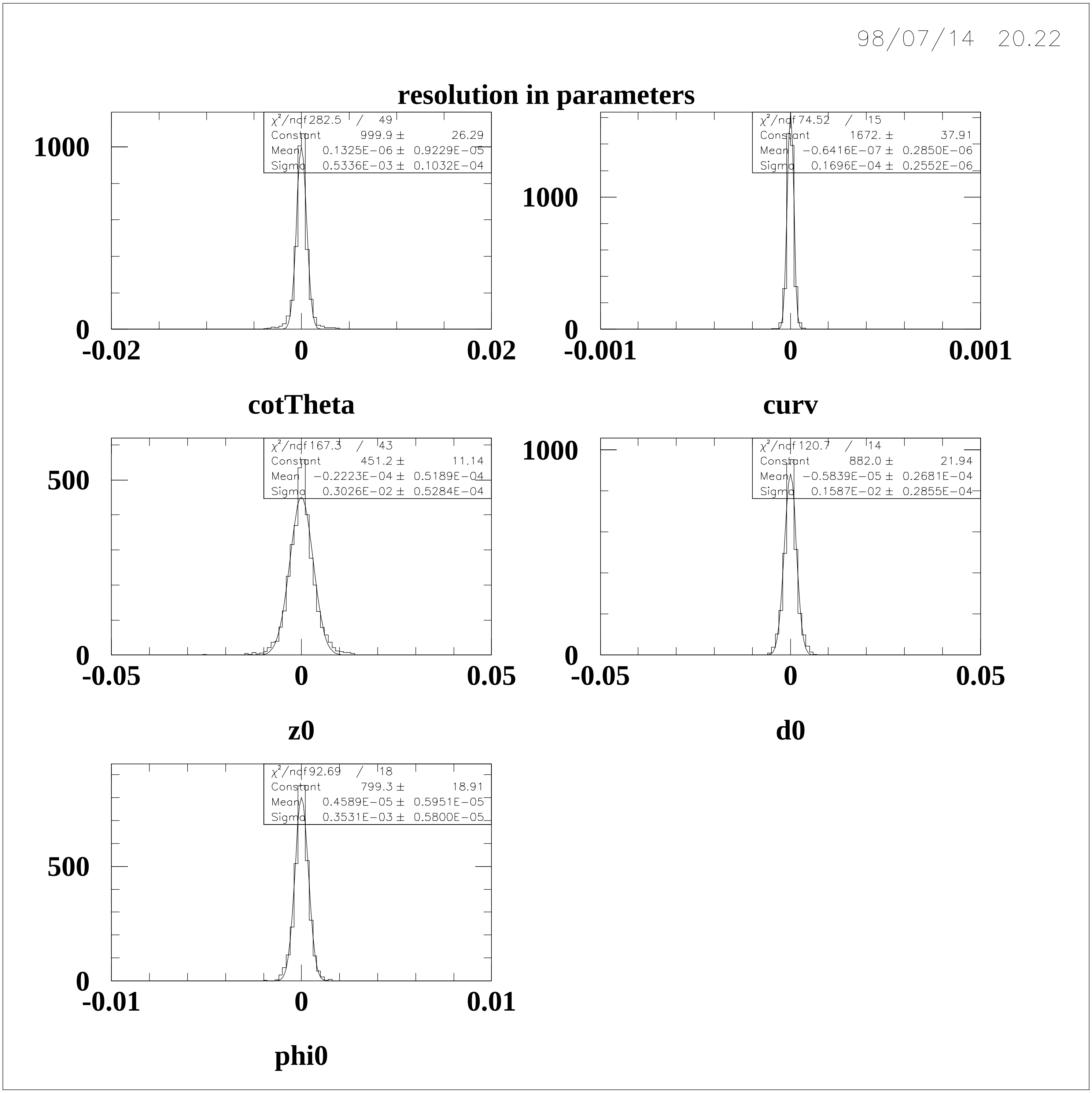
0) You can't do a very meaningful fit without incorporating multiple scattering.

1) You can't do much pattern recognition without incorporating the multiple scattering.

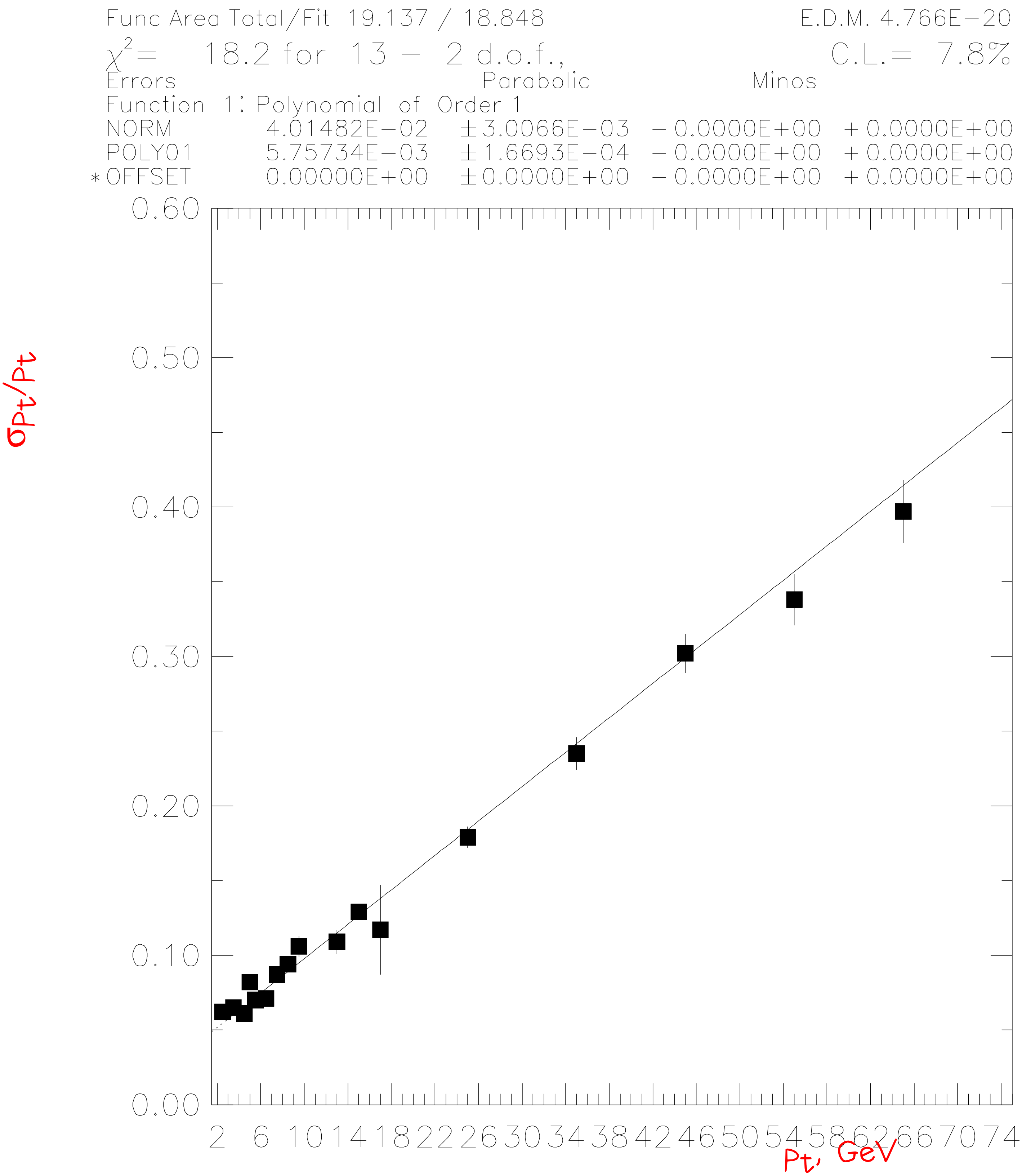
2) You can't do a straightforward segment merge.

3) How do you do a rϕ, rz + view merge pattern recognition?

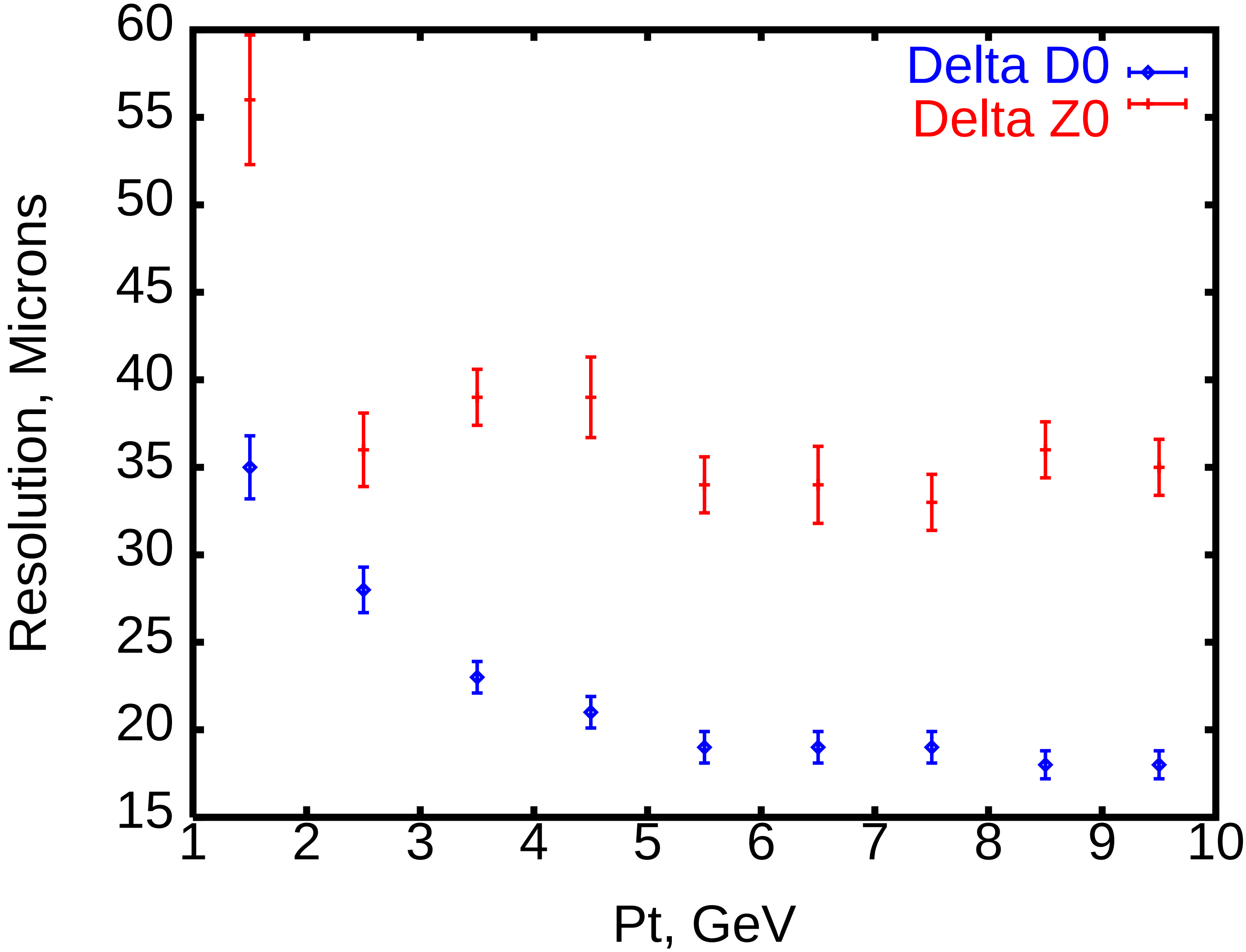
We can measure resolutions in all of the track parameters (high pt sample 1 GeV < pt < 100 GeV)



Momentum resolution as a function of transverse momentum.



Impact parameter resolution as a function of transverse momentum.



Summary of material and its effects:

1) There is ~ 10% of a radiation length in the SVXII and ISL detectors, most of it is located in the hybrids.

2) There is ~6% of an interaction length, in the SVXII and ISL detectors, most if it is located in the hybrids.

3) This is significantly more than in SVX'.

3) The biggest source of trouble are hadronic interactions, which have a high multiplicity.

4) Another source of trouble is absorption, on the order of 6% at normal, incidence.

5) Interactions double the number of charged particles seen in the SVXII and ISL detector.

6) Multiple scattering can be properly estimated and incorporated, but we need cooperation to keep the Simulation and Reconstruction in synch.

7) Mott scattering causes further trouble at momenta less than one GeV, and causes ~ 10% additional loss.

8) Resolutions are measured as a function of transverse momentum.

Pattern Recognition.

* Pattern recognition has been implemented for a long time, but has gotten a road test only very recently.

* The "default algorithm" (which is not frozen) requires:

  Low angle stereo crossing point in three layers, either:

  4-5-6
  2-4-5
  2-4-6
  2-5-6.

  Confirmation from at least two layers with 90 degree stereo.

* Candidates are then fit, rejected if $\chi^2 > 40$.

* Contention for hits allows at most one track to use each $r\phi$ or z hit in low angle stereo (seed) layers.

* Optimizer minimizes global χ^2 subject to this constraint. The optimizer takes little CPU and gives a vast improvement.

* $r\phi$ and z fits are carried out in the same step, with no matching step..

* Presently we have algorithms that work for low p_t events and algorithms that work for high pt events, but nothing so far that works for both!! (Solutions? Branch on trigger type?).

  Low P_t (bottom) threshold at 400 MeV
  High P_t (top) threshold at 1 GeV.

Input to Optimizer:

Constraints:

```
T0 + T1 <= 1
T2 + T3 + T4 + T5 <= 1
T6 + T7 <= 1
T6 + T7 <= 1
T8 + T9 + T10 <= 1
T8 + T9 + T10 <= 1
T6 + T7 <= 1
T2 + T4 <= 1
T11 + T12 <= 1
T0 + T1 <= 1
T8 + T9 + T10 <= 1
T6 + T7 <= 1
T11 + T12 <= 1
T0 + T1 <= 1
T2 + T3 <= 1
T4 + T5 <= 1
T2 + T3 + T4 + T5 <= 1
T11 + T12 <= 1
T2 + T3 + T4 + T5 <= 1
T3 + T5 <= 1
T2 + T3 <= 1
T4 + T5 <= 1
T8 + T9 + T10 <= 1
T0 + T1 <= 1
T11 + T12 <= 1
```

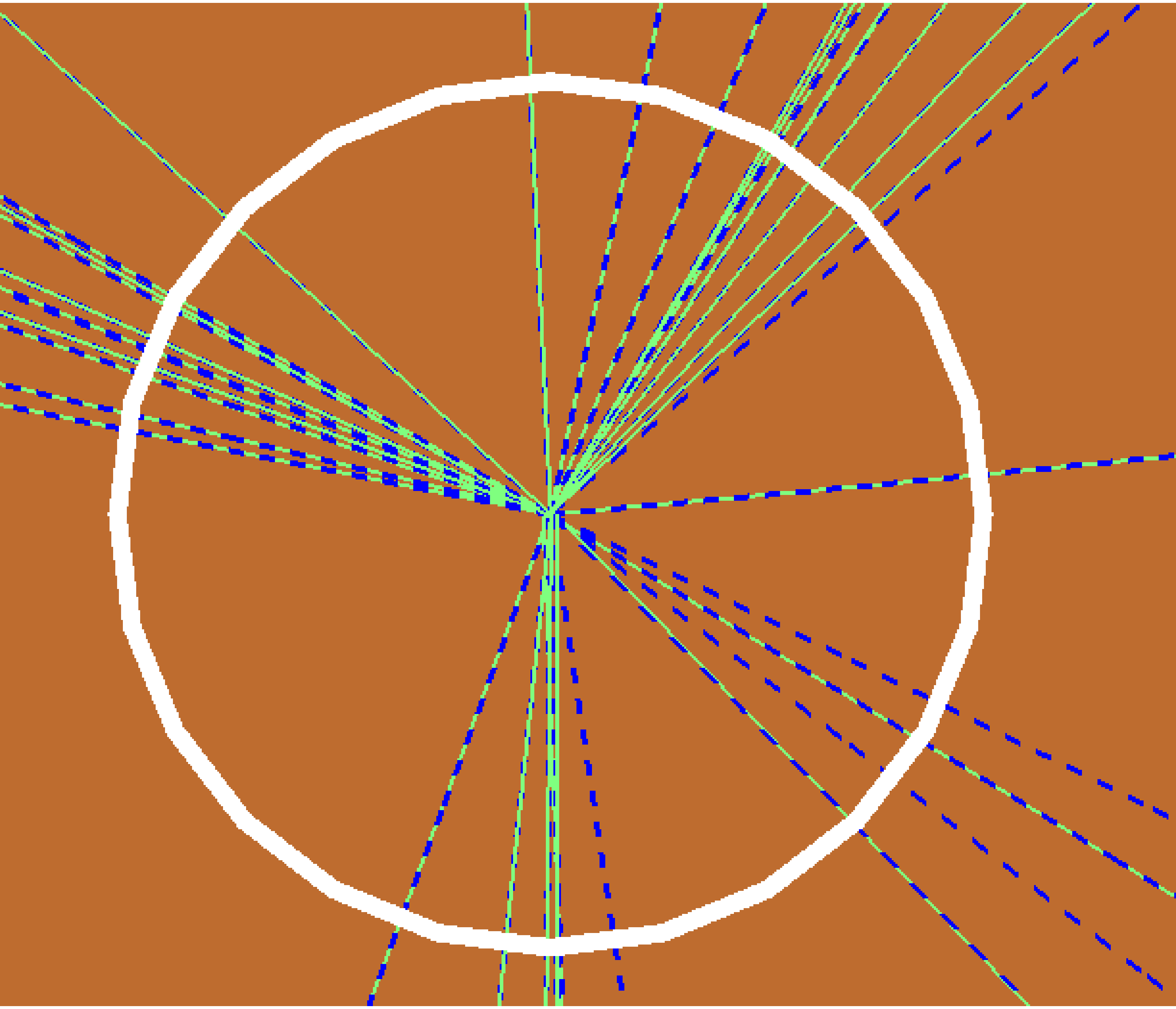
Objective function:

```
-36222*T0 + -36197*T1 + -22623*T2 + -36494*T3 + -37860*T4 +
-29563*T5 + -27313*T6 + -34569*T7 + -39371*T8 + -26684*T9 +
-28386*T10 + -36650*T11 + -36978*T12
```

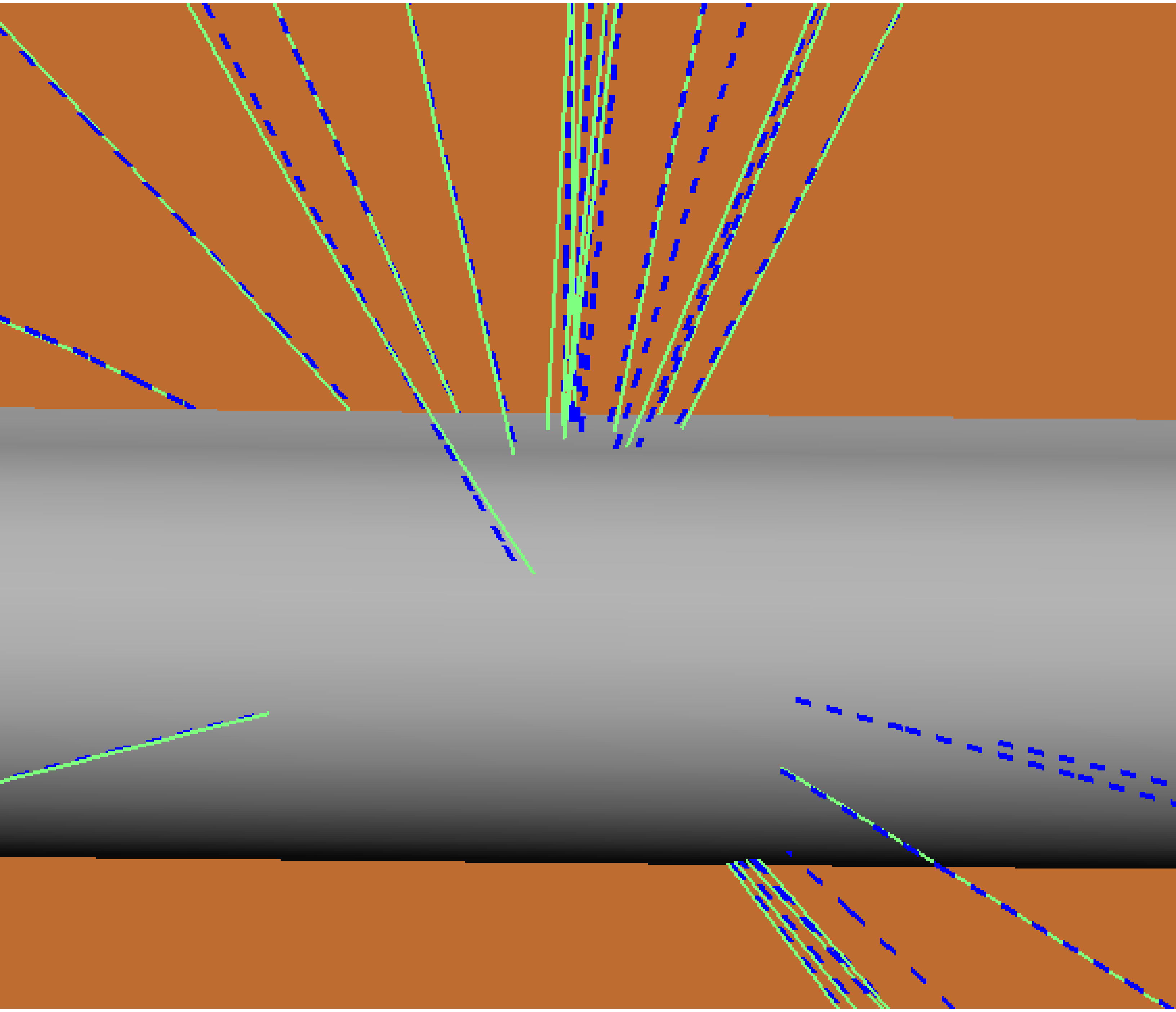
Output from Optimizer

```
New Local Minimum:   -162179    -1575024936 / 17967319 /       0.00
New Local Minimum:   -162507    -1575024935 / 17967321 /       0.00
New Local Minimum:   -169435    -1575024928 / 17967335 /       0.00
New Local Minimum:   -169763    -1575024927 / 17967337 /       0.00
New Local Minimum:   -176050    -1575024916 / 17967361 /       0.00
New Local Minimum:   -176378    -1575024915 / 17967363 /       0.00
New Local Minimum:   -183306    -1575024908 / 17967377 /       0.00
New Local Minimum:   -183634    -1575024907 / 17967379 /       0.00
New Local Minimum:   -184672    -1575024890 / 17967415 /       0.00
New Local Minimum:   -185000    -1575024889 / 17967417 /       0.00
>
+ exact solution.
```

A picture of a reconstructed ttbar event.



From the side:



23 CPU seconds / top event.
85 % efficiency

Some current problems:

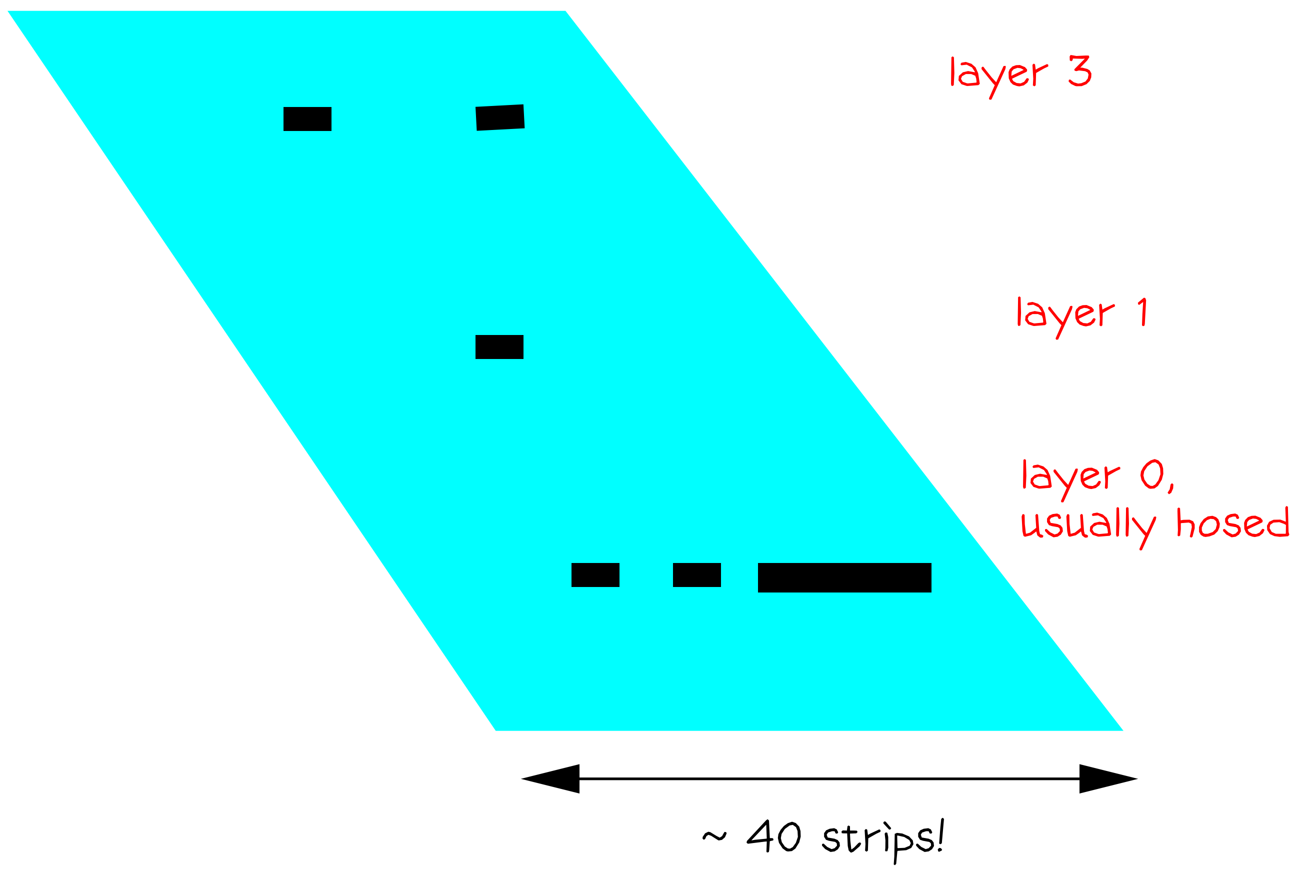
* The Z projection is a problem, needs a "Z-projection Tsar"

* A +/- 2 σ road into the 90 degree stereo layers of SVXII has a width of:

  2 cm (from COT)
  6 mm (from low angle stereo layers).

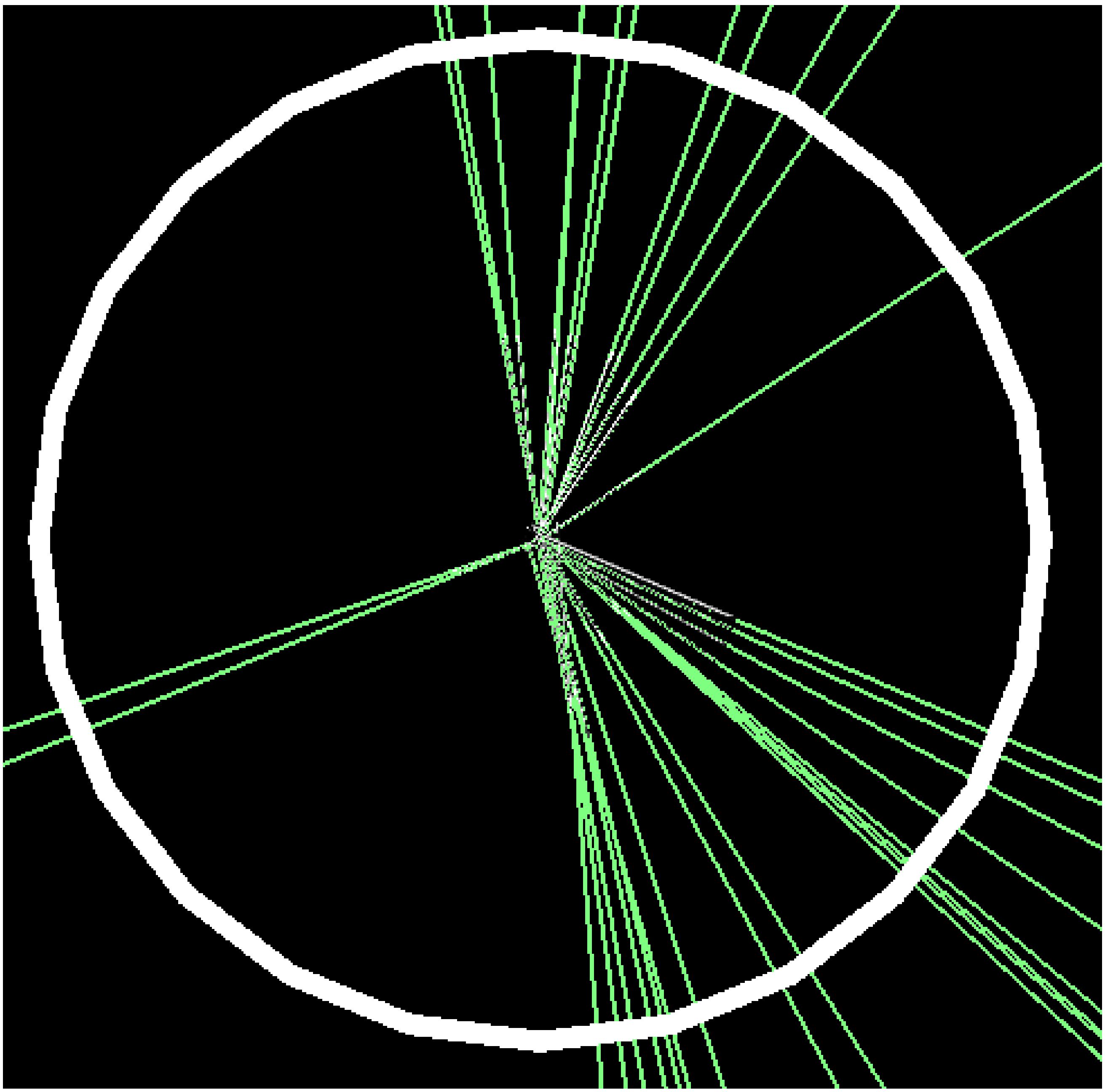
* By contrast, the hit resolution on the z layers is of order 40 μm.

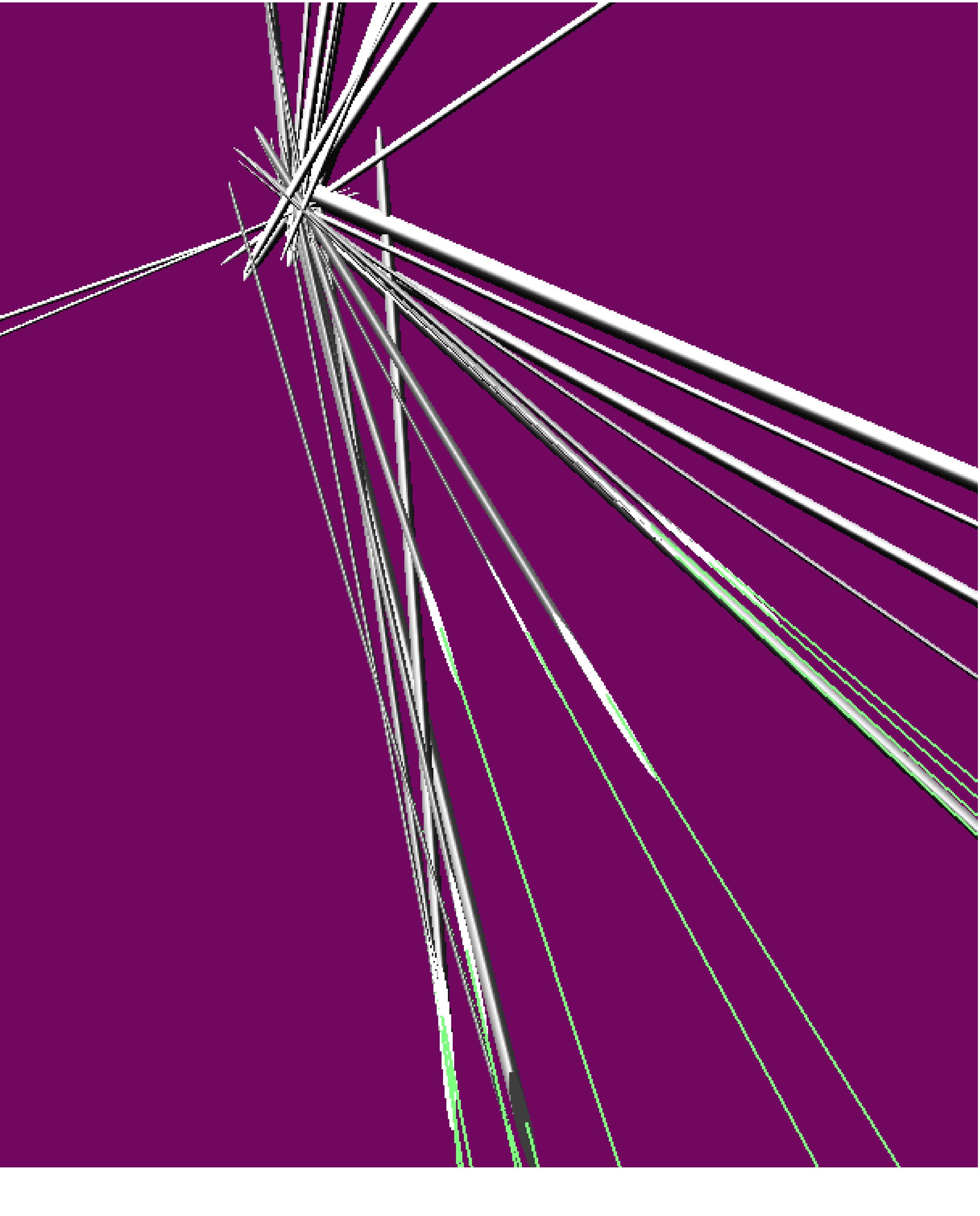
* In case of ambiguity, it is hard to decide which 90 degree stereo hits to use:



==>Would be nice to have: charge matching, charge-angle matching, angle-cluster length, more data-driven & sophisticated clustering.

Another top event:





Other problems:

* Working to use reconstructed tracks in some sample analyses.

* $B_s \rightarrow \overline{D_s}\ \pi+\ \pi-\ \pi+$

* Pretty good test of tracking, and independent of lepton ID.

* Revealed a problem in track merging,

* Making a simple weighted average between COT & Silicon is useless.

* Need to carry around scattering information and do a more careful final fit.

* Presently, a kludge is in place: take the momentum measurement from the COT and the other four quantities from the SVX, and splice the error matrix together.

* Give flat confidence level plots for fitted vertices and decent momentum measurement.

Also

* A bug has been found in bank I/O for silicon hit information.

* Standalone silicon test programs have a workaround: read objects not banks.

* The bug will have to be fixed, or SvxCotTracking will need to have a similar workaround.

* An overhaul of the cluster classes is coming soon, anyway.

Manual Page

Options | Sections 1 of 2 | Sections 2 of 2 | Directory of: (3) Subroutines

StartingPoint
SvxIslWafer
SvxIslWaferSet
TPool
TRYCotDigiSet
TRYGenPrimaryVertexSet
TRYRun2SiStripSet
TRYSiClusterData

CDF(C++) **Unix Programmer's Manual** **CDF(C++)**

SvxIslWafer

DESCRIPTION

An SvxIslWafer is an SiWafer, with an added SiDigiCode. The detector code encodes the Wafer's place within the ISL and SVXII system of ladders, half-ladder, layers, and barrels.

Author: Joe Boudreau

Include the string class header

CLASS ostream

```
using std::ostream ;
class SvxIslWafer:public SiWafer {
```

Public members

```
SvxIslWafer(const SiDigiCode  &detectorCode,
    const SiWaferDimension *waferDimension,
    const SiStripSpecification *phiStripSpecification,
    const SiZStripSpecification *zStripSpecification);
```

Constructor

```
const SiDigiCode & getDetectorCode() const;
```

Returns the detector code

Short term work to be done, to result in a useful exec.

- Still experimenting with best default algorithm.
- Optimization.
- How to do Top and Bottom??
- Problem with serialization of clustered data breaks the combined SVX-COT module.
- Track merge is incorrect, easily fixed.
- Material should be brought up-to-date
- Test with 1K top, bottom events.
- Output to Peter T's combined track bank.
- Documentation is available. (Everybody)

==> September 1 executable.

- Overhaul of libraries. (Chris Green)
- Overhaul of cluster classes. (Rick Snider)
- More optimization.(Chris & co.)
- Interface to calibration/geometry database. (??)
- Global strategies. (Karlsruhe, Peter T., Joe B. , Rick S)
- Regional tracking (Oxford)
- Test with 100 K top, bottom. (Chris)

==> Production executable.

- Stop cheating on the z vertex position. (Karlsruhe, Rick Snider)
- Z cluster model (New Mexico)
- Z projection improvements. (Padua)
- Studies of alignment begin. (Liverpool??)
- Customer service (everybody).
- Studies of samples representative of level 2 (Oxford + Level 3)

==> January executable.

==> More alignment (Liverpool?)

==> Mock data challenge. (Everybody)
==> Data taking, group will be active scrutinizing, tracking down, terminating systematic effects and coping with operational issues.
(Everybody + hopefully some SVXII / ISL hardware gurus)

Needed from the Monte Carlo Group:

-Big data samples so that we can check our own code before inflicting it on others, keep crashes and infinite loops to less than one per mil by September.

-Landau distributions and electronic noise in the strip data.

-Cooperation to incorporate a better Z-model for charge deposition being prepared by the New Mexico Group.

-Ability to turn off certain effects (Moliere tails, hadronic showers, & cetera).

Needed from the trigger group:

-Some effort to produce a data sample that looks like "typical" input to level 3.

Miscellany:

-Need a track reconstruction workshop to make global pattern recognition happen.